Integrated Full Wave Analysis of ICRF Waves in Burning Plasmas

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The behavior of burning plasmas can be very sensitive to the plasma state, such as the density, temperature and current density profiles and the existence of energetic ions, through the strong alpha-particle heating, the large bootstrap current fraction and the nonlinear transport processes. For reliable prediction of the burning plasmas, drawing up of the operation scenarios and the development of effective control schemes, comprehensive modeling codes are required. The integrated tokamak modeling code TASK [1] has been under development for this purpose with a component-based structure and a unified data exchange interface layer. It was applied to the self-consistent analysis of ICRF heating in the presence of energetic ions.

The deviation of the momentum distribution function from the Maxwellian affects the propagation and absorption of the ICRF waves. The full wave module TASK/WM was extended to use the wave dispersion module TASK/DP that calculates the dielectric tensor for an arbitrary momentum distribution function. The wave electric field calculated by TASK/WM is used to describe the time evolution of the distribution function by the bounce-averaged 3D Fokker-Planck module TASK/FP. It can calculate the distribution functions of all particle species and include the nonlinear collisional interaction with each other and the radial diffusion with model diffusion terms. The effects of NBI heating and alpha-particle heating as well as the energetic tail formation due to the ICRF heating are consistently described. The power partition and the power deposition profile for various ICRF scenarios in ITER accompanied with the NBI heating and the alpha-particle heating are examined.

The finite gyroradius effect of energetic ions is another issue to be resolved for consistent full wave analysis. The differential operator approach is usually based on the expansion up to the second order with respect to $k_\perp \rho_i$, where $k_\perp$ is the perpendicular wave number and ρ_i is the ion gyroradius, and is applicable only for $k_\perp \rho_i < 1$. The integral operator approach is formulated in a toroidal configuration and implemented in TASK/WM. This approach is based on the explicit integral along the gyro orbit, applicable for any value of $k_\perp \rho_i$ and expected to require less computer resources than the spectral approach. The power absorption by energetic ions as well as the interaction with the ion Bernstein wave is evaluated in the ITER plasma and the results are compared with those of the differential operator approach. At present the integral operator approach is limited to the Maxwellian distribution or the Maxwellian with a cutoff in energy. The formulation for an arbitrary momentum distribution function and a consistent quasi-linear momentum space operator will be discussed

Finally the integrated simulation of the ICRF heating scenario in ITER by the TASK code including the 1-1/2 transport analysis will be presented.

[1] A. Fukuyama et al, Proc. of 20th IAEA Fusion Energy Conf., IAEA-CSP-25/CD/TH/P2-3 (Vilamoura, 2004)